PCT WORLD INTELLECTUAL PROPERTY ORGANIZATION
International Bureau

INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(51) International Patent Classification 6 : F02B 71/00 // 71/06 · A1

(11) International Publication Number: WO 97/28363

(43) International Publication Date: 7 August 1997 (07.08.97)

(21) International Application Number: PCT/NO97/00023

(22) International Filing Date: 29 January 1997 (29.01.97)

(30) Priority Data:
960402 30 January 1996 (30.01.96) NO

(71) Applicant *(for all designated States except US)*: KVÆRNER ASA [NO/NO]; Prof. Kohts vei 5, N-1324 Lysaker (NO).

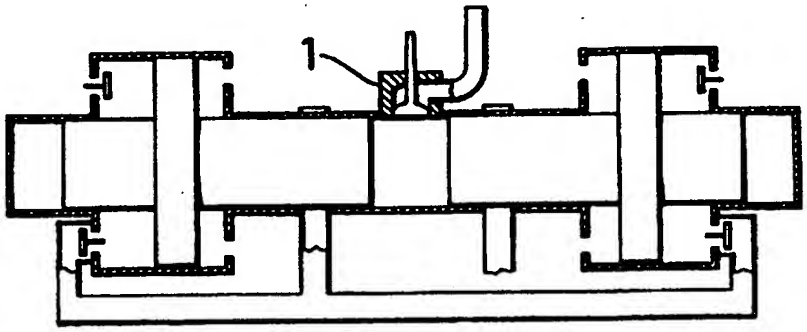
(72) Inventors; and
(75) Inventors/Applicants *(for US only)*: FØRDE, Magnar, Jarle [NO/NO]; Kåre Kongsbrors vei 2, N-7562 Hundhamaren (NO). KVAMSDAL, Rolf [NO/NO]; Jarlsborgvei 18A, N-7041 Trondheim (NO).

(74) Agent: ONSAGERS PATENTKONTOR A.S; P.O. Box 265 Sentrum, N-0103 Oslo (NO).

(81) Designated States: JP, RU, US, European patent (AT, BE, CH, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE).

Published
With international search report.

(54) Title: AN IMPROVEMENT IN FREE-PISTON DEVICES



(57) Abstract

Improvement in diesel free-piston gas generators with, e.g., a cylinder in which there are provided two pistons, which are moved synchronously towards or from each other. At the ends of the cylinder the cylinder and the pistons define a combustion chamber which can be connected to a pipe for the supply of high-energy exhaust gas to a consumer thereof. According to the invention, the device comprises at least one exhaust gas valve, which is arranged in an exhaust gas port provided in the cylinder section, which port constantly communicates with the combustion chamber. The exhaust gas valve is operated by an activator which is controlled, e.g., by a computer which via sensors very rapidly establishes values for operating parameters for the gas generator.

FOR THE PURPOSES OF INFORMATION ONLY

Codes used to identify States party to the PCT on the front pages of pamphlets publishing international applications under the PCT.

AM	Armenia	**GB**	United Kingdom	**MW**	Malawi
AT	Austria	**GE**	Georgia	**MX**	Mexico
AU	Australia	**GN**	Guinea	**NE**	Niger
BB	Barbados	**GR**	Greece	**NL**	Netherlands
BE	Belgium	**HU**	Hungary	**NO**	Norway
BF	Burkina Faso	**IE**	Ireland	**NZ**	New Zealand
BG	Bulgaria	**IT**	Italy	**PL**	Poland
BJ	Benin	**JP**	Japan	**PT**	Portugal
BR	Brazil	**KE**	Kenya	**RO**	Romania
BY	Belarus	**KG**	Kyrgystan	**RU**	Russian Federation
CA	Canada	**KP**	Democratic People's Republic of Korea	**SD**	Sudan
CF	Central African Republic			**SE**	Sweden
CG	Congo	**KR**	Republic of Korea	**SG**	Singapore
CH	Switzerland	**KZ**	Kazakhstan	**SI**	Slovenia
CI	Côte d'Ivoire	**LI**	Liechtenstein	**SK**	Slovakia
CM	Cameroon	**LK**	Sri Lanka	**SN**	Senegal
CN	China	**LR**	Liberia	**SZ**	Swaziland
CS	Czechoslovakia	**LT**	Lithuania	**TD**	Chad
CZ	Czech Republic	**LU**	Luxembourg	**TG**	Togo
DE	Germany	**LV**	Latvia	**TJ**	Tajikistan
DK	Denmark	**MC**	Monaco	**TT**	Trinidad and Tobago
EE	Estonia	**MD**	Republic of Moldova	**UA**	Ukraine
ES	Spain	**MG**	Madagascar	**UG**	Uganda
FI	Finland	**ML**	Mali	**US**	United States of America
FR	France	**MN**	Mongolia	**UZ**	Uzbekistan
GA	Gabon	**MR**	Mauritania	**VN**	Viet Nam

An improvement in free-piston devices

The invention concerns an improvement in free-piston devices with

- a cylinder device with at least one cylinder section,
- a piston which is provided in the cylinder section,
- a combustion chamber and a return chamber which are defined by the cylinder section and the piston, the piston being capable of being moved in its longitudinal direction alternately towards the combustion chamber for compression of a gas therein or in the opposite direction for compression of air in the return chamber, and
- a pump or compressor device for the supply of air to the combustion chamber.

Such free-piston devices may be of the diesel type and be employed, e.g., as gas generators.

In known diesel free-piston gas generators, during its movement the piston uncovers exhaust gas ports in the cylinder for discharging the exhaust gas from the combustion chamber. This uncovering of the exhaust gas ports which is only dependent on the piston's position, restricts the possibility of changing the compression by controlling the beginning of the compression in the combustion chamber and thereby a part load regulation of the gas generator. In practice this means that during operation the gas generator has to be run the whole time with almost nominal output.

It is also known to provide separate return and compressor chambers, with the result that the gas generator requires a great deal of space.

It is also known for the end section of the piston which faces the combustion chamber to be equipped with only one sealing ring. The result of this can be that the ports are not completely sealed in relation to the outlet ports.

In known free-piston generators the volume of the return chamber is fixed in the sense that the volume is only established of that section of the gas generator's free piston which projects into the return chamber, with the result

that this return chamber cannot be used for regulation of the gas generator's operation.

In known free-piston generators, moreover, there is a risk that the free piston may come into contact with an adjacent end wall of the cylinder section and that these components can be damaged.

The object of the invention is to provide an exhaust gas device of the above-mentioned type which improves the possibility of regulating the gas generator as mentioned above.

The characteristics of the device according to the invention are presented by the characteristic features indicated in the claims.

The invention will now be described in more detail with reference to the drawing which schematically illustrates embodiments of the device according to the invention.

Fig. 1 is a schematic longitudinal section through a free-piston gas generator with two cylinder sections with respective pistons and with coincident longitudinal axes together with a common combustion chamber for the cylinder sections situated in neighbouring areas of the cylinder sections, this section resembling the section which is illustrated in the single figure for the simultaneous application.

Fig. 2 is a longitudinal section through a gas generator with a piston.

Fig. 3 is a longitudinal section through a gas generator with two cylinder sections and pistons, comprising in principle two gas generators of the type which resembles that which is illustrated in fig. 2, these extending with coincident longitudinal axes and their return or buffer chambers being placed against each other.

Fig. 4 is a longitudinal view through a gas generator with a cylinder section and a piston, with a combined buffer or return chamber and compressor device.

Fig. 5 is a longitudinal section through four jointly operating gas generators of the type which is illustrated in fig. 4.

Fig. 6 is a longitudinal section through a gas generator with a single piston and a cylinder device with a cylinder which has a combustion chamber at each end.

Fig. 7 is a cross section through the section in the vicinity of a combustion chamber of a cylinder device for a gas generator, sections of the device being cut away.

For a more detailed description of the gas generator's design, reference should be made to the applicant's above-mentioned, simultaneously submitted application. A method is described therein for controlling the stroke of gas generators of the above-mentioned type by means of a computer which is programmed to vary the mass or the energy of the air in the return chamber in order thereby to vary the piston's stroke movement. This computer is arranged to establish values of operating parameters of the free-piston gas generator via an array of sensors such as pressure, temperature and position sensors. Features will now be described and claimed which are based on features described in the above-mentioned application, but which for the sake of simplicity are not repeated here. It will be understood that these basic features should be considered to also be included in the present application.

In fig. 1 there is illustrated a gas generator of the type which is illustrated in the applicant's simultaneous application. Instead of the pistons uncovering exhaust gas ports at each stroke, in the centre of the cylinder device there is provided a channel which communicates with the combustion chamber, and in which there is provided an exhaust gas valve 1 for controlling the discharge of the exhaust gas from the combustion chamber. Thus, the discharge of exhaust gases from the combustion chamber can be independent of an opening of outlet ports in the cylinder sections by means of the pistons. This exhaust gas valve 1 can be controlled, e.g., by the computer which is described in the applicant's simultaneous application, thereby permitting operation of the gas generator during part load.

Furthermore, cylinders can hereby be obtained which are symmetrical about a transverse median plane with regard to inlet ports, as well as individual stroke lengths and heat load. Assembly and dismantling of the gas generator is simplified and thereby also the maintenance thereof.

In fig. 2 there is illustrated a gas generator with a single piston 2 which is provided in a cylinder 3 corresponding to one half of the cylinder device which is illustrated in the applicant's simultaneous application. In this embodiment, however, an exhaust gas valve 4 like that described in connection with fig. 1 is installed at the combustion chamber on the end surface of the cylinder.

In order to prevent a collision between the end section of the piston which faces the combustion chamber and the opposite cylinder end wall, in a ventilation chamber 9 on the side of the compressor piston which faces away from the compressor chamber 6, a cylindrical, axially extending dowel 7 is mounted on the enlarged section 5 of the piston 2. The cross section of the dowel 7 is adapted to the cross section of an axially extending hole 8, which is provided in the compressor housing wall, and through which the air in the ventilation chamber 9 communicates with the ambient air. When the piston end which projects into the combustion chamber comes too close to the opposite cylinder end wall, the dowel 7 is brought into the hole 8, thereby closing the ventilation chamber 10. A further movement of the piston thus causes a progressive increase in the pressure of the enclosed air and brakes the piston's movement, preventing a collision between the piston and the cylinder end wall. This design requires guide devices (not shown) which prevent rotation of the piston about its longitudinal axis.

In order to prevent a collision between the piston and the cylinder end wall at both dead centre positions, extra air can be supplied by means of the aforementioned computer to the return or buffer chamber in order to prevent the piston from striking the buffer chamber end wall, or air can be removed from the buffer chamber in order to reduce the speed at which the piston is brought into the combustion chamber.

If little clearance is provided between the piston and the buffer cylinder wall, a relatively high buffer chamber pressure can quickly be provided which counteracts a collision between the piston and the buffer chamber end wall.

Fig. 2 illustrates the arrangement of the compressor's valves which supply compressed air to the cylinder's inlet ports when the piston is moved away from the combustion chamber. In contrast to the reversed valve arrangement, the former valve arrangement is advantageous, since there is no need for any pressure chamber between the compressor chamber 6 and the inlet ports, and

thus no hysteresis loss occurs in connection with a related accumulation of pressure energy. This device further permits variation of the compression ratio without such a variation influencing the inlet air compression. One drawback, however, is that small tolerances are required for the pistons at the outer dead centre position, i.e. at the dead centre position at which the piston is located when it is remote from the combustion chamber. In order to counteract this, it can be advantageous for the return or buffer chamber volume to be adjustable. This can be achieved by providing the cylinder end wall at the buffer chamber in the form of a screw (not shown) which is screwed axially into the cylinder end section. By providing a motor which can rotate this cylinder end wall, thereby screwing it into or out of the cylinder, the buffer chamber volume can easily be varied. Thus the energy content of the buffer chamber can be controlled, especially during power control. The motor can be controlled, e.g. by the computer which is described in the applicant's above-mentioned simultaneous application.

In fig. 2 it is shown that the air from the compressor is passed to a compressed air container 11 from which air may be drawn, passed, e.g., to a gas turbine via a valve 12 and mixed with the exhaust gas from the gas generator. The filling of the combustion chamber during the suction phase can thereby be controlled. Such control can also be provided, e.g., by controlling the suction valves (not shown) in the cylinder.

Instead of positioning the combustion and buffer chambers as shown in fig. 1, these can change places as shown in fig. 3. Each cylinder section thereby obtains its own combustion chamber which is located at the extreme end of the cylinder section, thus enabling the cylinder sections to be of the same design as the cylinders for standard diesel motors. The cooling of the cylinders at the combustion chambers can thereby be improved. In order for the gas generator to function properly, each piston must have a separate buffer chamber. For this reason a central partition 15 is provided, thus creating two separate buffer chambers 16,17.

In fig. 4 a gas generator is illustrated with a piston where the compressor chamber also acts as a return or buffer chamber for returning the piston towards the combustion chamber after it has reached the external dead centre position. In this arrangement, regulation such as by means of the aforementioned computer and as mentioned in connection with fig. 3 must be

implemented in order to ensure that the energy of the air in the compressor chamber is always sufficiently great to return the piston, thus enabling the stroke for compression of the gas in the combustion chamber (the compression stroke) to be performed.

Since a gas generator with only one piston is not in dynamic balance, a generator of this kind can be provided together with and operate jointly with corresponding gas generators, the movement of the pistons being phase shifted.

As illustrated in fig. 4 four gas generators of the type which is illustrated in fig. 3 are arranged in a row on a common frame (not shown). For example, the pistons of the two outer gas generators 21,22 can be operated in the same phase. These pistons are phase shifted by 180° in relation to the pistons of the two inner gas generators.

From each gas generator's compressor chamber air is led via a pipe 25 to the respective gas generators' inlet ports via a compressed air container 26.

From this container a pipe 27 extends to a shut-off valve 28 which in turn is connected via a pipe 29 to a manifold 30 which connects pipes similar to pipe 29 to one another. Exhaust gas is passed from the exhaust gas port to the pipe 29 via a pipe 31.

The exhaust gas is passed from the manifold 30 to a chamber 35 where the pressure fluctuations in the exhaust gas are moderated to some extent. It is passed from there to a gas turbine 32 which is arranged to drive a turbocompressor 33. During operation the turbocompressor 33 draws in ambient air, compresses it and passes it to the inlet valve of each gas generator's compressor via an intermediate cooler 34 and an air manifold 36.

Instead of pipes 25 from the compressor to the inlet ports, channels (not shown) can extend in the respective cylinders.

In fig. 6 there is illustrated a gas generator with a single piston 51 which has a central, enlarged section which forms a compressor piston section 52. On each side thereof, the piston 51 has a working piston section 53 and 54.

The piston 51 is provided in a cylinder device 55 comprising a central, enlarged compressor cylinder section 56. On each side thereof, the cylinder device has a working cylinder section 57 and 58 with smaller diameter.

The piston sections 52,53,54 are arranged to be moved together axially forwards or backwards in the respective cylinder sections 56,57,58.

Together with end walls of the compressor cylinder section 56, the compressor piston section 52 defines two compressor chambers 61,62. Each compressor chamber has an inlet valve and an outlet valve 63,64 and 65,66.

Together with the end areas of the working cylinder sections, the ends of the working piston sections define combustion chambers 71,72.

In the working cylinder sections 57,58 there are provided air inlet ports 75,76 and exhaust gas outlet ports 77,78. In the exhaust gas outlet ports there are provided valves 81,82,83,84 which can be operated by related activators 85,86,87,88. Furthermore, in the working cylinder sections there are provided fuel injection nozzles 89,90.

The outlet valve 65 for the right compressor chamber 62 is connected via pipes to the inlet port 75 for the left working cylinder section 57 and in addition connected via a shut-off valve 91 to the inlet of a gas turbine 95 which is fed via pipes with exhaust gas from both working cylinders.

Moreover, the outlet valve 64 for the left compressor chamber 61 is connected via pipes to the inlet port 76 for the right working cylinder section 58 and in addition connected via a shut-off valve 92 to the inlet of the gas turbine 95.

The gas turbine 95 is arranged to drive a turbocompressor 96 and, e.g., an electrical generator 97. The turbocompressor draws in ambient air and passes this in a compressed state to the compressor chambers' inlet valves 63,66 via an intermediate cooler 98.

In this case too the exhaust gas valves' activators 85-88 can be operated by a computer as mentioned above.

The advantage of an exhaust gas generator according to fig. 6 is that the combustion chambers are placed at the extreme ends of the cylinder device, thus providing easy access to the adjacent cylinder sections which become very hot during running, and enabling them to thereby receive a good cooling. Moreover, the heavily loaded exhaust gas ports can be replaced by known per se valve devices which can be satisfactorily cooled in the known manner.

The shut-off valves 91,92 can be opened for the supply of cold air to the exhaust gases from the gas generator in order thereby to reduce the temperature of the gas which is supplied to the turbine 95.

Since this gas generator only has one cylinder, four gas generators, e.g., may advantageously be placed on a common frame in order to obtain an approximately dynamically balanced device as mentioned above in connection with the device which is illustrated in fig. 5.

In fig. 7 there is illustrated a central section of a gas generator with two pistons 101,102 which are provided axially and in the same cylinder 103. Together with the cylinder 103, the ends of the pistons which are located opposite each other define a combustion chamber 104. A fuel injection nozzle 105 is provided for supplying fuel to the combustion chamber 104.

For example, the left piston 101 is illustrated at the inner dead centre position, i.e. in the position at which it is located when it has been inserted furthest into the combustion chamber 104, and the right piston 102 is illustrated at the outer dead centre position. It will be understood, however, that during operation the pistons are substantially located simultaneously at the inner or the outer dead centre position.

Near the end which faces the combustion chamber there is mounted on each piston a pair of sealing rings 111,112,113,114, where the sealing rings in each pair, 111,112 and 113,114 respectively are provided with a spacing which enables them to provide a seal on each side of the exhaust gas ports or the inlet air ports, considered in the axial direction when the pistons are brought into a suitable position. Each piston thus constitutes a shut-off valve, which is important for the regulation of output, since gas generators usually have at least two cylinders whose piston pairs can be started and stopped in turn.

It will be understood that further devices are provided, e.g. for starting of the gas generators, sensors etc. for the computers etc., even though such devices are not specifically illustrated in the figures.

PATENT CLAIMS

1. An improvement in free-piston devices with

a cylinder device with at least one cylinder section,

a piston which is provided in the cylinder section,

a combustion chamber and a return chamber which are defined by the cylinder section and the piston, the piston being capable of being moved in its longitudinal direction alternately towards the combustion chamber for compression of a gas therein or in the opposite direction for compression of air in the return chamber, and

a pump or compressor device for the supply of air to the combustion chamber,

characterized in that the device comprises at least one exhaust gas valve, which is arranged in a port provided in the cylinder section, which port constantly communicates with the combustion chamber, and which exhaust gas valve is operated by an activator.

2. Improvement according to claim 1,

characterized in that the return chamber forms part of the compressor device.

3. Improvement according to claim 1 or 2,

characterized in that the end section of the piston which faces the combustion chamber is equipped with two sealing rings which are arranged with spacing in the piston's longitudinal direction, and there is provided a device for movement of the piston to a position where the sealing rings are located on each side of either the inlet port or the outlet port for the cylinder device, in addition to securing the piston in this position.

4. Improvement according to one of the preceding claims, characterized in that the volume of the return chamber can be regulated.

5. Improvement according to claim 4, characterized in that the return chamber wall includes a through-going threaded bore into which a screw is mounted for alteration of the volume of the return chamber.

6. Improvement according to claim 1, wherein the compressor is an axial piston pump which is driven by the free piston, and which includes a compressor piston which is axially movable in an associated compressor cylinder, wherein the compressor cylinder on one side of the compressor piston and together therewith defines a compressor chamber and on the other side of the compressor piston defines a space which is ventilated to the ambient air via an axially extending passage, characterized in that the compressor piston has an axially extending compressor piston section whose cross section is adapted to the passage cross section, and which is arranged to project into the passage and close it when the free piston is located close to an end wall of the cylinder section.

7. Improvement according to claim 1, wherein the compressor is an axial piston pump which is driven by the free piston, and which includes a compressor piston which is axially movable in an associated compressor cylinder, wherein the compressor cylinder on one side of the compressor piston and together therewith defines a compressor chamber, characterized in that it comprises a control device which via a position sensor continuously establishes the position of the free piston in the cylinder section, and a compressed air container which is connected via a pipe and a shut-off valve to the compressor chamber, and the control device is arranged to open the shut-off valve for the introduction of compressed air into the

compressor chamber in order to counteract a contact of one of the free piston's end sections with a thereto adjacent end section of the cylinder section.

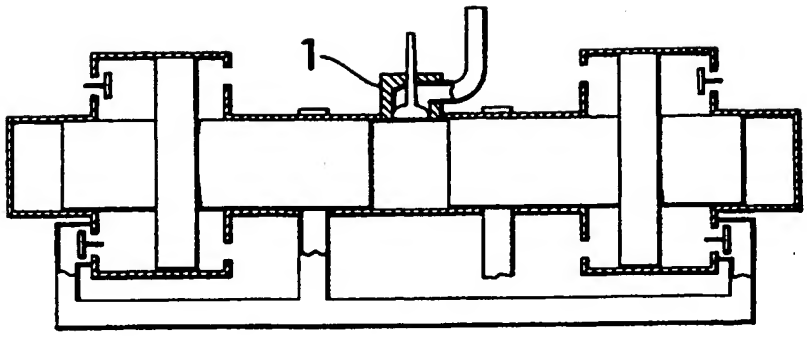


Fig.1

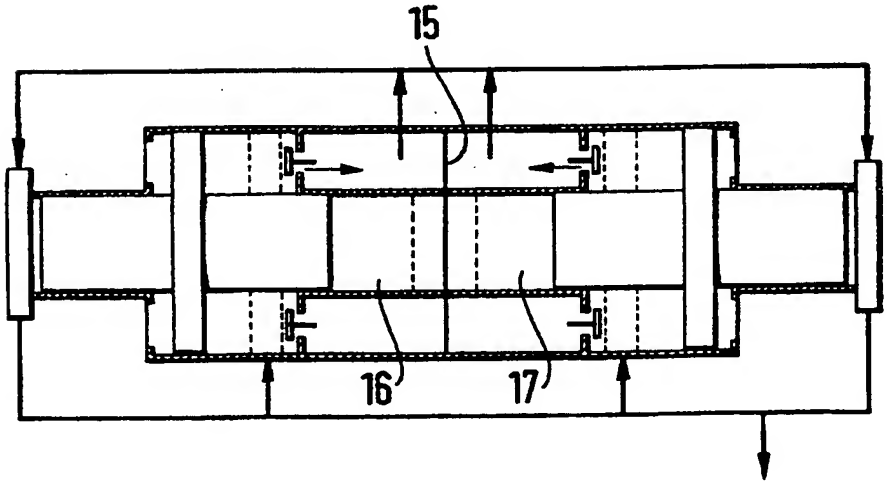


Fig.3

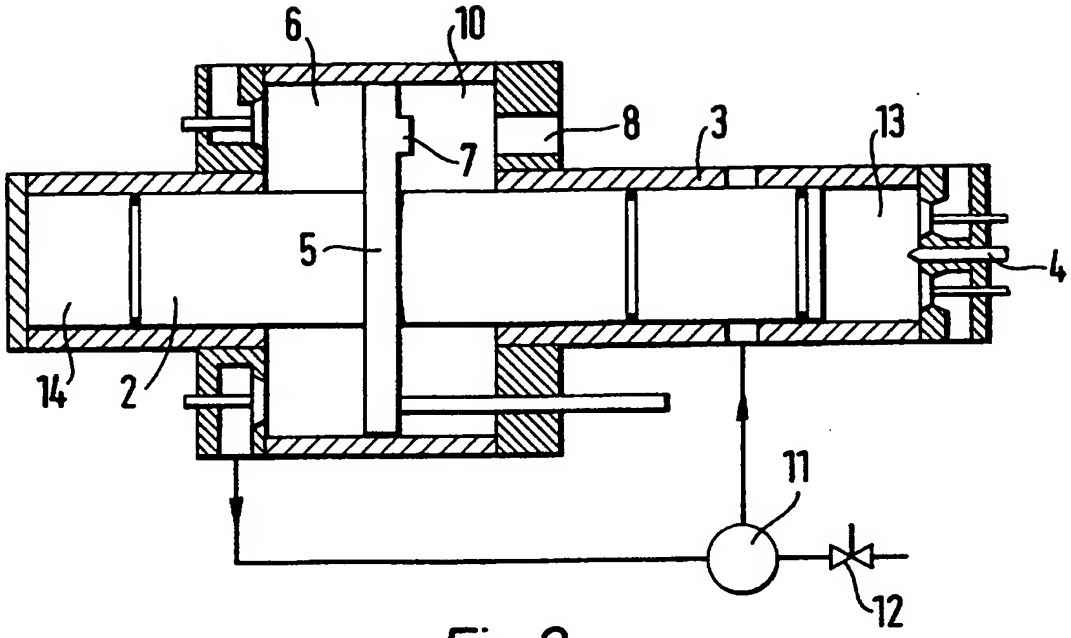


Fig. 2

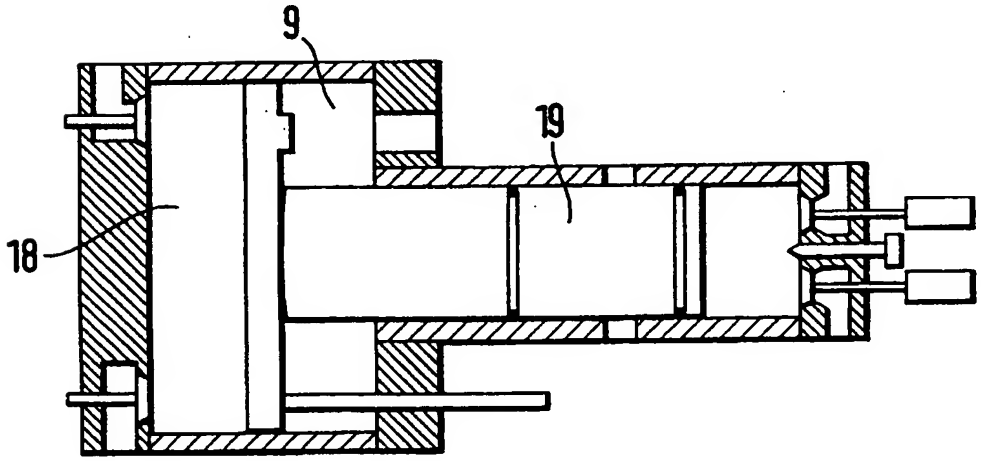


Fig. 4

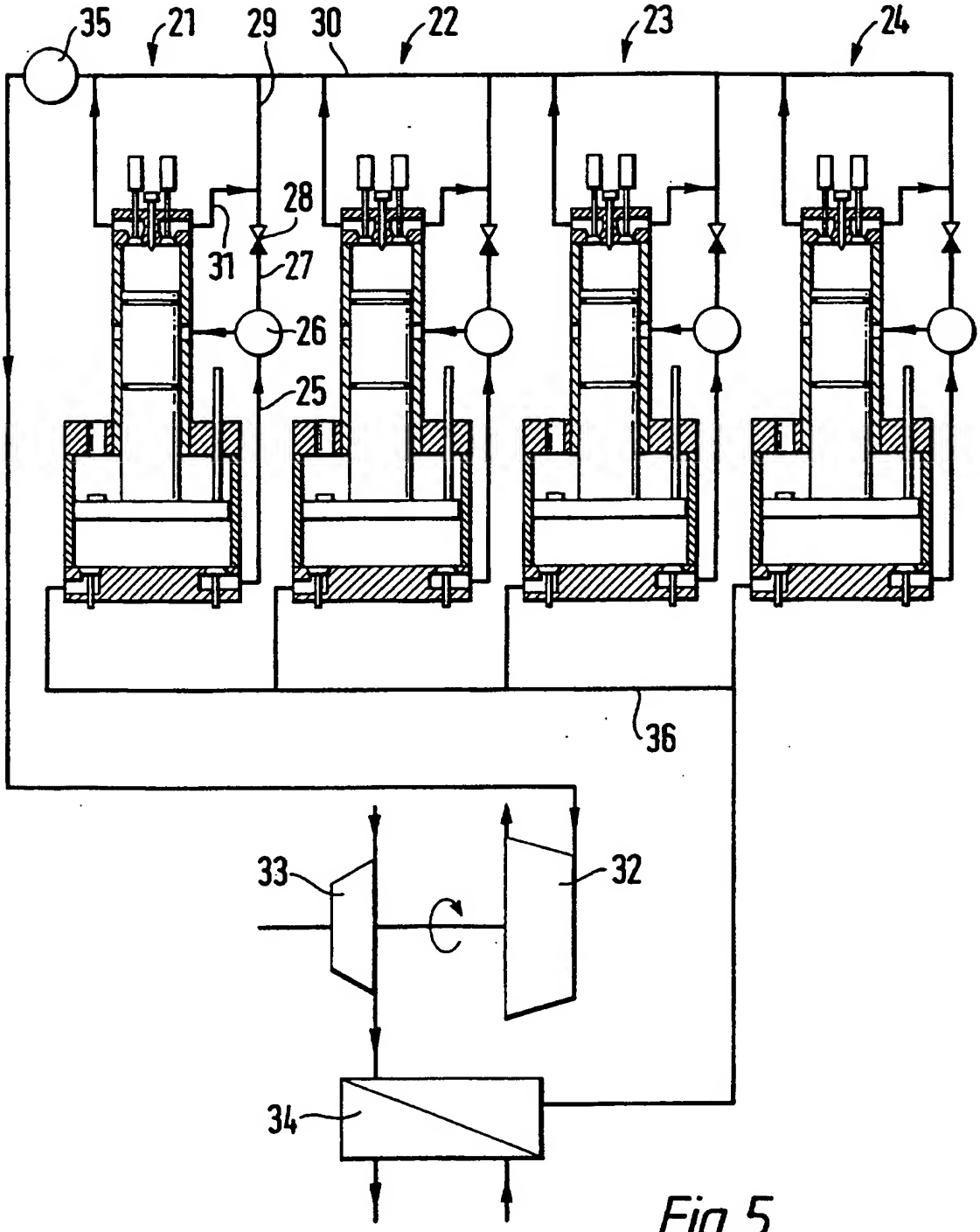


Fig.5

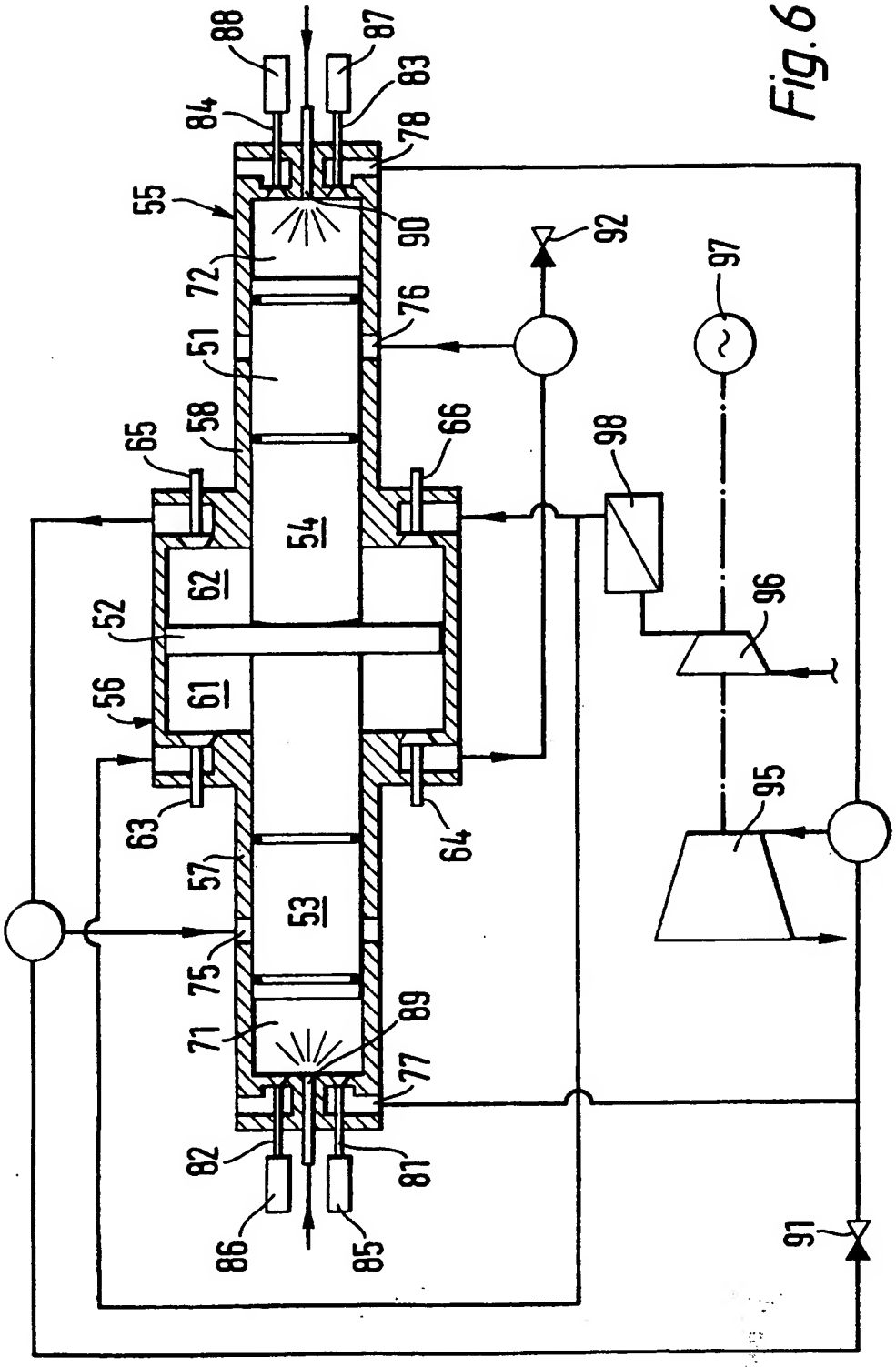

88
87
84
83
78
55
90
92
97
72
76
51
58
66
65
98
54
62
52
96
61
56
95
63
64
57
53
75
89
71
77
82
81
86
85
91

Fig.6

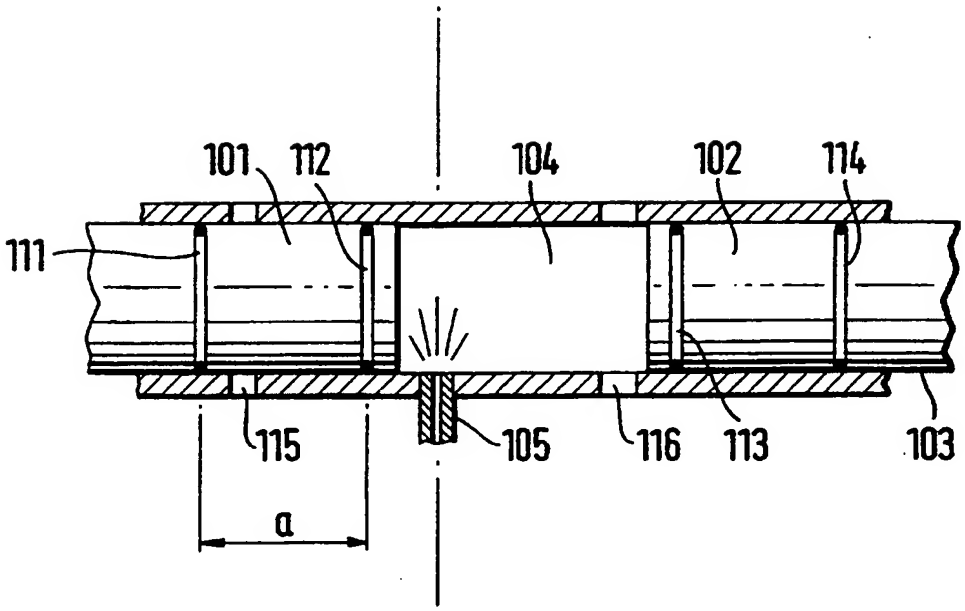


Fig. 7

INTERNATIONAL SEARCH REPORT

International application No.
PCT/NO 97/00023

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 4369021 A (HEINTZ), 18 January 1983 (18.01.83) -- --------	1-7

INTERNATIONAL SEARCH REPORT

Information on patent family members

02/04/97

International application No.
PCT/NO 97/00023

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 4653274 A	31/03/87	US 4561252 A	31/12/85
		US 4653273 A	31/03/87
		US 4662177 A	05/05/87
		US 4665703 A	19/05/87
		US 4672813 A	16/06/87
		US 4702205 A	27/10/87
		US 4760701 A	02/08/88
		US 4820480 A	11/04/89
US 4876991 A	31/10/89	NONE	
US 5363651 A	15/11/94	NONE	
GB 2214569 A	06/09/89	NONE	
US 4369021 A	18/01/83	NONE	